Mathematics and Science Initiative Concept Paper

Background

Not since the Soviet Union launched *Sputnik* in 1957, has the federal government spearheaded a major initiative promoting mathematics and science education. Within twelve years of *Sputnik*, America had upgraded its mathematics and science education program, launched satellites, seen its own astronauts orbit the Earth, and landed the first man on the Moon. However, since that time, federal attention to mathematics and science education has lost focus and waned, particularly where elementary and secondary education are concerned. Student achievement scores now fall below international standards, the scientific literacy of our young people does not meet levels needed to participate fully as productive citizens in the 21st Century, and the pipeline for jobs in mathematics, science, technology, and engineering has slowed to a trickle. The report *Road Map for National Security: Imperative for Change*[i], also known as the Hart-Rudman Commission Report, released months before the attacks of September 11, reminds us how critical it is to develop a new generation of citizens who have the mathematical, scientific, technological, and engineering skills to create new strategies and technologies to keep America safe and prosperous. The ability to inspire a new generation of scientists, mathematicians, engineers, and technicians starts in our nation's schools. To call attention to the need to improve mathematics and science instruction across the country, the Administration will launch a major new five-year Mathematics and Science Initiative to improve mathematics and science achievement. The Initiative will focus on three main goals:

1.) **Conducting a broad-based public engagement campaign that draws attention to the need for mathematics and science education in our nation's schools.** Students need to envision where a career in mathematics and science can take them, and to understand that they must prepare now for such opportunities. Parents need to know what children should be studying to prepare them for success in a world that requires the ability to understand and apply knowledge of mathematics and science. The public must also understand that advances in technology and productivity, that will help the U.S. remain competitive in the global economy, hinge on all students learning algebra, physics, and other scientific and technical subjects. The Initiative will work with the business community and professional organizations of mathematicians, scientists, and engineers, as well as educators, to: (a) sponsor events that excite students and parents about careers in science, technology, engineering and mathematics (STEM); (b) bring these professionals into schools to work with students and help teachers improve instruction; and (c) send teachers and students to work with these professionals as interns, summer or part-time employees, and consultants at the scientific job site. Businesses and federal departments and mission agencies will be involved in providing STEM examples, developing the messages, leveraging the dissemination efforts, and coordinating their programs and materials with state standards in mathematics and science.

2.) **Initiating a major campaign to recruit, prepare, train, and retain teachers with strong backgrounds in mathematics and science.** The campaign will seek to accomplish two objectives: increase the number of new entrants to the teaching profession who have a strong background in mathematics and science, and strengthen the mathematics and science knowledge of current and future teachers. Pursuit of the first objective will promote promising alternative routes in the states to recruit such teachers. Existing federal programs in the U.S. Department of Education, such as Transition to Teaching[ii] and Troops to Teachers[iii], will have a special focus on bringing highly qualified recent college graduates and mid-career professionals with strong subject matter background in mathematics and science into teaching. It will also focus on working with colleges of arts and sciences in institutions of higher education, not just teacher training programs, to ensure that tomorrow's mathematics and science teachers have high levels of content knowledge. The second objective will focus on providing current teachers with effective professional development programs that develop their content knowledge and show evidence of boosting student achievement.

3. **Developing a major academic research base to improve our knowledge of what boosts student learning in mathematics and science in the classroom**. Teachers need to know what programs and strategies are effective in improving student achievement in mathematics and science. A rigorous research agenda, as mandated in the No Child Left Behind (NCLB) legislation[iv], will be undertaken to specify the learning processes that are essential for success in a wide range of learners, to identify the effective instructional strategies that capitalize on knowledge about learning in mathematics and science, and to effectively transmit that information to the teachers who need it. Several areas of inquiry have been identified to develop a scientifically rigorous research base of practical value. Research foci described in this Initiative aim to: identify workforce requirements and citizenship needs related to mathematics and science, understand student learning in mathematics and sciences, explain the dynamics of successful interventions, and develop and apply valid assessment tools to measure progress of students and programs.

The Office of Science and Technology Policy (OSTP), the U. S. Department of Education (ED), the National Science Foundation (NSF), the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), as well as other federal departments and agencies involved in education and workforce development, will collaborate to promote this Initiative. There is a need to add coherence to the wide variety of federal efforts in mathematics and science education. The combined efforts should add up to an impact on mathematics and science learning without the pieces losing their appropriateness to the mission of their home agency or department. At this time they are idiosyncratic rather than rooted in an overall plan that helps fulfill missions and they are, therefore, not as effective as they might be. Once the programs become coordinated and known across government and with the public, they will be effective in achieving their

goals, and become accountable to the public that supports them, the Congress that funds them, and the Administration that staffs them.

Section I: The Need To Increase Public Awareness of the Vital Importance of Mathematics and Science Education

Our nation's education system is failing to equip our children with the essential mathematics and science skills required in an increasingly competitive global economy. Nearly three-quarters of our nation's 4th and 8th graders and nearly four-fifths of our 12th graders are scoring at levels below "proficient" in mathematics and science for their grades.[v] International mathematics and science assessments demonstrate that as U.S. students progress through their educations they score progressively worse than do students in the rest of the developed world. Furthermore, national and international benchmarks confirm that minority students and students from low-income families perform particularly poorly in relation to other U.S. and international students.

In light of poor U.S. student performance in mathematics and science, a national campaign is needed to inform parents, students, educators, and the general public about the importance of mathematics and science learning in our changing society. Strengthened science and mathematics education would contribute to our nation's prosperity by spurring economic growth and generating a more highly skilled workforce; it would also afford greater opportunities for students to pursue postsecondary education and training or to enter higher-wage careers.

This campaign will also confront negative public perceptions regarding mathematics and science, especially the misconceptions that only "nerds" need to study mathematics and science and that it is acceptable for adults to say that "I was never any good at mathematics." Parents will learn that while they may not have needed a rigorous mathematics and science background to be successful, their children will. The Initiative will enlist the aid of state and local education agencies, businesses, professional organizations, religious, and non-profit organizations to promote mathematics and science awareness and to provide the requisite expertise to strengthen mathematics and science education.

Poor U.S. Student Achievement in Mathematics and Science

- ***One out of every three students in 4th, 8th, and 12th grade performs at the lowest level on the NAEP mathematics assessment.*** While trends over the past ten years show that students have improved their mathematical skills, the proportion of students scoring at the "below basic" level is still 31 percent for 4th graders; 34 percent for 8th graders; and 35 percent for 12th graders. A large majority of students score at the two lowest levels, "basic" and "below basic."[vi] In fact, black and Hispanic 12th graders demonstrate a similar set of mathematics skills as white 8th graders in the NAEP, and only 3 percent of minority students score at the proficient level in mathematics. These statistics are even more troubling in light of recent analyses of NAEP items, which show that NAEP mathematics standards are lower in comparison to exams given in Singapore. In fact,

NAEP mathematics items for 8th graders match those given to 5th graders in the Asian city-state.[vii]

- ***A substantial achievement gap between white students and both black and Hispanic students persists in mathematics across a 10-year span despite achievement gains for all three groups. In science a similar gap persists across a 4-year span, but with minor changes in overall achievement levels.*** The report *The Nation's Report Card: Mathematics 2000* revealed that while white, black, and Hispanic students at grades 4 and 8 made gains on the National Assessment of Educational Progress (NAEP) since 1990, the large gaps between these subgroups' performance have remained relatively unchanged. In the 2000 assessment, white students, in all three grades, had higher scores, on average, than back or Hispanic students, and the differences in scores were substantial. For example, White fourth graders scored 236, on average, in 2000 compared to 205 for black students and 212 for Hispanic students. In eighth grade the comparable numbers were 286 compared to 247 and 253. These large gaps between subgroups' performance have remained relatively unchanged since 1990. White students had higher scores in 2000 than in 1990 at grade 12, when no significant difference in scores was found for black or Hispanic students.[viii] In science, NAEP results showed only a few, modest changes between the 1996 results and those of 2000 (this science assessment was first administered to nationally representative samples of fourth-, eighth-, and twelfth-grade students in 1996). There were no significant differences at grade 4; at grade 8, the average score for American Indian students declined; and at grade 12, the average score for white students declined. Across all three grades in 2000, white students had higher scores, on average, than black or Hispanic students. The large gaps between subgroups' performance have remained relatively unchanged since 1996.[ix]

- ***Student performance in science is worse than mathematics.*** The share of students at the "below basic" level in the NAEP science assessment is large, especially for 12th graders. Almost half (47 percent) of 12th graders score at the "below basic" level, while 34 percent of 4th graders and 39 percent of 8th graders are at that level.[x]

- ***8th graders in the U.S. are outperformed in mathematics and science by students in almost all industrialized nations, except Italy and New Zealand.*** The 1999 Third International Mathematics and Science Study–Repeat (TIMSS-R) reports that U.S. students score significantly lower than 8th graders in 14 countries. Singapore students score the highest in mathematics while students from Chinese Taipei score the highest in science.[xi]

Mathematics and Science as Spurs to Economic Growth and Competitiveness

- ***Science and mathematics are key drivers in an economy that relies heavily on emerging technologies.*** New technologies facilitate the nation's standard of living by making workers more productive. As noted by The National Commission on Mathematics and Science Teaching for the 21st Century (Glenn Commission), since 1996, national productivity has increased, on average, by 2.6 percent per year. If we can maintain that rate—all other things being equal—the nation's standard of living will double approximately every 25 years.[xii] Recent evidence suggests that improved productivity in the computer-producing sector and the effect of computer technology on workers together account for much of the recent acceleration in U.S. labor productivity.[xiii] The first wave of technology has enabled the country to do traditional

jobs with fewer workers, but it has also increased the number of jobs in new fields that need mathematics, science, engineering and technology workers.

- ***Other nations have stepped up their efforts in creating a well-trained workforce in science and technology, often competing with U.S. workers.*** The Glenn Commission also put us on notice about specific examples of other nations' efforts to upgrade their workforces through enhanced scientific and technological education. Singapore, for example, reputedly has the most technologically intensive workforce in the world. Israel now produces more technology-based startups than anywhere outside Silicon Valley; its high-tech exports account for a quarter of global sales. Drawing on a young, skilled, and well-educated workforce, Ireland now produces 60 percent of all PC business-application software sold in Europe.[xiv]

- ***Many of today's fastest growing jobs require a solid mathematics or science background.*** Of the 20 fastest-growing occupations projected by the U.S. Bureau of Labor Statistics (BLS) through 2010, 15 of them require substantial mathematics or science preparation. Most of the fastest-growing occupational areas will reflect continued growth in computer technology—a field that imports talent in order to stay competitive—and health services. The fastest-growing jobs in mathematics and science fields will increase by nearly 6 million in 2010.[xv] While the number of young adults 18-to 24-years old will grow by 3 million over this same decade, 56 percent of these adults will be minority students who are underrepresented in higher level mathematics and science classes in high school and college. (U. S. Census Bureau; www.census.gov/population/projections/nation/summary). Increased numbers of H 1 (b) visas have been the nation's response to shortages in highly skilled workers, but when the shortages reach the millions, that solution is no longer viable. Without a considerable investment of time, energy, and funding in improving America's K-12 educational system in science and mathematics, American companies will find no alternative but to go overseas to countries that have better skilled workforces.

Greater Opportunities to Attend College and Enter High Wage Professions for Students of Mathematics and Science

- ***Students of all income levels who take rigorous mathematics and science courses in high school are more likely to go to college, and among low-income students (students in the bottom third of the income distribution), the difference is particularly dramatic.*** Students from low-income families who took Algebra I and geometry were almost three times as likely to attend college as those who did not. While 71 percent of low-income students who took algebra I and geometry went to college, only 27 percent of low-income students who did not take algebra I and geometry went on to college. The differences are also dramatic among students from middle- and high-income families: 94 percent of students from high-income families, and 84 percent of students from middle-income families who took algebra I and geometry went on to college, while 60 percent of students from high-income families and 44 percent of students from middle-income families who did not take algebra I and geometry still went on to college.[xvi] This study demonstrates how critical it is for teachers to have high expectations for their students and to ensure that all students take these courses. Many have criticized this study by saying that the low-income students in those classes were identified as "college material" because of their higher achievement in middle school courses and therefore were steered into the mathematics and science courses required for success in college matriculation

and graduation. Tracking of students often has the effect of expanding opportunities for some students, while denying opportunities for students who are not perceived by their teachers as successes. While that may not make as much of a difference for students from middle and higher-level incomes, it is devastating for low-income students and minority students.

- ***Students with higher-level mathematics skills earn more.*** Even among students who only earned a high school diploma, those with highest-level mathematics skills earned more than double (108 percent more) than those with the weakest skills.[xvii]

- ***Scientists and engineers earn higher salaries and are employed at very high rates.*** The median annual salary of scientists and engineers in 1997 was $52,000 for bachelor's degree holders and $59,000 for master's recipients. By comparison, the median annual salary of individuals employed in non-science and engineering fields in 1997 was $40,000 for bachelor's degree holders; $50,000 for master's recipients. The unemployment rate was 1.5 percent for all workers in science and engineering occupations in 1997, while the national unemployment rate was 4.8 percent. [xviii]

Student and Public Perception of Mathematics and Science

- ***Public opinion calls for better science education in schools.*** Ninety-three percent of Americans say students need stronger education in science to be prepared for the new inventions, discoveries, and technologies that increased investment will likely bring. In fact, 85 percent agreed that improving pre-college science education in their state should be one of their governor's top priorities.[xix]

- ***A majority of teachers (57 percent) thinks that students are taught enough mathematics, science, and computers in schools.*** However, a majority of the public thinks otherwise (52 percent). Only 28 percent of teachers would be "very concerned" if international test scores showed American students were doing poorly, compared to 56 percent of the public and 63 percent of community leaders.[xx] This mirrors the Metropolitan Life study, which showed that teachers expected less than 27 percent of their students to go to college, while 80 percent of the students and 67 percent of their parents expected the students to go on to college. Low expectations held by teachers must be changed if students are to have the opportunity to be successful.

- ***College students wish they had more rigorous mathematics and science training.*** Forty percent of college students say they wish they'd had a stronger pre-college science and mathematics education. Seventy percent believe science and mathematics education should be strengthened for the next generation of students.[xxi]

Strategies To Promote Mathematics and Science Education

- ✓ Develop Presidential and Secretarial speeches and articles to highlight NCLB provisions to strengthen teaching, assessment and accountability in mathematics and science.

- ✓ Increase media involvement by working with newspapers, cable shows, businesses and others to highlight the importance (and beauty) of mathematics and science in advertisements and other media products; incorporate such messages in TV shows; and launch contests/puzzles.

- ✓ Have each Federal agency identify specific ways it can engage students to strengthen mathematics and science awareness.

- ✓ Work with the business community, engineering, mathematics and science organizations (e.g., Education Department partnerships and industry organizations) to volunteer their employees or members with strong mathematics/science skills to encourage and support instruction and tutoring, particularly in areas consistent with their core business objectives.

- ✓ Work with faith-based and community-based organizations to encourage students to study mathematics and science, including through obtaining federal grants.

Section II: Recruit, prepare, and retain teachers with strong mathematics and science backgrounds

There is a serious shortage of highly qualified mathematics and science teachers. New and aggressive efforts are required to attract and retain teachers of mathematics and science with an extensive knowledge of the subject matter. Research suggests that teachers who know their content have a positive impact on student learning. The goals of this Initiative are to improve the quality of mathematics and science teachers entering the profession, increase content knowledge and teaching skills of current teachers of mathematics and science, and establish mechanisms to retain highly qualified teachers of mathematics and science in K-12 schools.

The Mathematics and Science Partnerships program authorized under Title II of *The No Child Left Behind Act* will bring together state education agencies, institutions of higher education, local school districts, and community-based organizations to focus on effective practices that can be replicated across the country. The program will fund a variety of activities including in-depth training of pre-service and in-service teachers in mathematics and science, the identification of rigorously researched mathematics and science curricula and distance learning programs, and incentives to recruit and retain college graduates with degrees in mathematics and science. For FY 2003, the Administration has proposed allocating $200 million to NSF and $12.5 million to ED for the program.

Current State of Teacher Quality

- ***Teacher quality linked to student value-added mathematics performance.*** Researchers used data from two Tennessee districts to identify the "effectiveness" of teachers, based on the average annual growth of students in their classes. When students were assigned to three highly effective teachers in a row, these students scored at the 83rd percentile in mathematics at the end of 5th grade. However, when students were assigned to three ineffective teachers in a row, they scored at the 29th percentile in mathematics.[xxii] The NCLB Act recognizes the importance of teacher quality by providing states and districts with new money, ideas and flexibility to improve the quality of their teacher workforce.

- ***A sizeable number of mathematics and science teachers do not have a major or minor in their field, especially those who teach in high-poverty and high-minority schools, despite research that indicates the importance of teachers' subject-matter knowledge to student outcomes.*** The percentage of mathematics teachers without a major or minor in mathematics has remained high for middle school teachers. In 1999-2000, a majority of middle school mathematics teachers (51.5 percent), and a large percentage of middle school science teachers (40 percent) lacked either a major or minor in their field. These figures are virtually identical to those of 1993-94 of 50.3 percent and 39.2 percent, respectively. High school mathematics and science teachers are better prepared than are middle school teachers, although the share of high school teachers who lack adequate preparation has risen since 1993-1994. For example, in 1999-2000, 14.5 percent of high school mathematics teachers and 11.2 percent of high school science teachers lacked a major or minor in their field as compared to 11.6 percent and 7.6 percent respectively in 1993-94.[xxiii]

The NCLB Act aims to address this issue by requiring that by 2005, all teachers demonstrate subject matter knowledge through a state test; completion of an academic major; or advanced degrees, coursework, or certification.

- ***On average, mathematics or science teachers at all levels scored lower on the mathematics section of the SAT compared to mathematics or science majors not interested in teaching.*** Mathematics or science teachers scored 557 on the mathematics section of the SAT, below the average score of 593 for mathematics or science majors who do not go into the teaching profession.[xxiv] The differences are even greater when examining only mathematics teachers. In addition, only 21 percent of mathematics majors go into the teaching profession and teach mathematics, and a much smaller proportion (8 percent) of mathematics majors become teachers of a subject other than mathematics. In other words, the vast majority of mathematics majors (71 percent) choose not to go into the teaching profession.[xxv] Mathematics teachers at all levels scored 568 on the mathematics section of the SAT, whereas mathematics majors not going into the teaching profession scored 624.[xxvi]

- ***Mathematics or science teachers earned a slightly higher annual income than non-mathematics or non-science teachers ($24,932 versus $24,227) three years after they graduated from college.*** However, the income disparity is much more pronounced between mathematics or science teachers in comparison to mathematics or science majors who did not become teachers. While mathematics or science teachers, on average, earned $24,932 in 1997, non-teachers who majored in mathematics or science earned $32,041 during the same time period, an income difference of 28.5 percent. The income gap is even more substantial (38.3 percent) when graduate students are excluded from the analysis since they are less likely to earn as much money during their years of advanced schooling.[xxvii]

Licensing Requirements

- ***Several states do not require secondary teachers to take a licensing examination in their subject, and a few do not require teachers to take any licensing examination.*** Although 44 states require candidates for secondary licenses to take some kind of licensing examination, only 29 require them to take tests in the subject area they will teach.[xxviii] The main teacher certification examinations, the Praxis and National Evaluation Systems, cover content that can be found in a broad high school curriculum. Only a few questions go beyond calculus or address concepts typically learned in the first two years of college.

- ***Many states allow prospective mathematics teachers with relatively low scores on licensing examinations to become teachers.*** Of the 29 states that use the Praxis I exam, a basic skills test, most states set their minimum cut scores in mathematics around the 20th-40th percentile range.[xxix] Virginia is the only state that sets its minimum score at the 50th percentile. Of the 5,000 Virginia teacher candidates who took the PRAXIS I, 35 percent failed the mathematics portion. Nationwide, nearly half of all teacher candidates would have failed to make the Virginia cut. In areas of short supply, states may still require candidates to take the test but will waive the requirement for minimum performance.

- ***State certification requirements may limit otherwise qualified mathematics and science candidates from teaching.*** *Students enrolled in courses taught by teachers in the Teach for America (TFA) program, who did not attend education schools, improved their academic performance above and beyond the students of other new teachers, and performed as well as students taught by all teachers in Houston.* In mathematics, students of TFA teachers again had greater achievement gains than students of other new teachers. There was no statistical difference between the demographic characteristics of students of TFA teachers and students of all other teachers in the district.[xxx]

Lack of Rigor in K-12 Coursework

- ***U.S. mathematics coursework lacks the rigor of our higher-scoring competitors.*** One study estimates that "hard problems" on NAEP 8th grade assessment are equivalent to 5th grade questions on Singapore mathematics assessments.[xxxi] However, very little research has been directed towards identifying the necessary content that must be introduced and learned at each grade level to ensure success at the next level.

- ***U.S. schools are much more likely to allow calculators in the early grades than schools in highest mathematics achieving countries.*** Singapore, Korea, Japan, Chinese Taipei, and Hong Kong all score high on international mathematics exams and each restricts or prohibits calculator use in the elementary grades until mastery has been demonstrated.[xxxii] In addition, fourth graders who used calculators more frequently in their classrooms had lower scores on the 2000 National Assessment of Educational Progress in Mathematics.[xxxiii]

Professional Development

- ***Professional development that is focused on specific teaching strategies increases teachers' use of those strategies in the classroom.*** This effect is even stronger when professional development has features of high quality. These strategies include: 1) the use of technology for learning to think; 2) the use of instructional methods for developing thinking skills; and 3) the use of assessment strategies for developing thinking skills.[xxxiv]

- When professional development is focused on academic content and curriculum that is aligned with standards-based reform, teaching practice and student achievement are likely to improve. Cohen and Hill compared the effects of teacher participation in professional development specifically targeted to a mathematics education reform initiative in California to teacher participation in special topics and issues workshops that were not linked to the content of the mathematics initiative (e.g., workshops in techniques for cooperative learning). The more time teachers spent in targeted training on the framework and curriculum of the mathematics reform, the more their classroom practice changed in ways that were consistent with the mathematics reform, and the more they learned about the content and standards for that reform. Teachers who participated in special topics and issues workshops showed no change in their classroom practice or knowledge related to the reform. Teachers who participated in the focused training and whose classroom practice moved towards incorporating the framework of the new math initiative had students who scored higher on a test of the math concepts imparted by the new curriculum.[xxxv] This study and others

suggest that when professional development is focused on academic content and curriculum that is aligned with standards-based reform, both teaching practice and student achievement are likely to improve.[xxxvi]

Strategies to Improve Teacher Quality in Mathematics and Science Education

- Identify alternative routes for certification to recruit those with strong content backgrounds into teaching, including recruiting mid-career professionals.

- Engage scientists and mathematicians as participants with K-12 and university educators in national efforts to identify the appropriate content knowledge and instructional strategies of their disciplines for teachers.

- Establish partnerships between K-12 communities, state departments of education, and institutions of higher education to share responsibility for preparing and supporting teachers, and ensure that the courses offered by institutions of higher education for pre-service and in-service teachers provide teachers with strong backgrounds in appropriate content and good strategies for teaching. Prepare to add professional societies and groups, as well as business and industry to these partnerships in appropriate ways.

- Establish intensive summer institutes for mathematics and science teachers throughout the nation to nurture leaders in mathematics and science education. This will both improve content knowledge among teachers and increase the numbers of teachers who are strongly qualified to provide leadership in improving the mathematics and science education of their peers (*e.g.*, as trainers or as trainers-of-trainers) and represent mathematics and science teachers as standards, curricula, assessments, materials, resources, and plans are developed and refined.

- Encourage the development of incentive plans for mathematics and science teachers, including cash awards, loan forgiveness programs, and differential pay plans.

SECTION III: Developing A Major Academic Research Base On Effective Mathematics And Science Instruction And Assessment

The goal of raising student achievement lies at the very center of *No Child Left Behind* (NCLB). The research portion of the mathematics and science Initiative is designed to establish a foundation of scientifically based knowledge upon which efforts to improve student achievement levels in mathematics and the sciences may be based. Consistent with the aims of NCLB, this research agenda will generate knowledge needed to help students develop mathematical and scientific proficiency. A research agenda in support of this Initiative must generate scientific knowledge that describes how all students can best learn mathematics and science across different grade levels. To advance the goals of the mathematics and science Initiative, the fundamental research foundations and structure of the proposed research agenda must be created.

Lack of Sufficient Research on What Works in Mathematics and Science

Coordinated and sustained investments in the improvement of mathematics education have been inadequate. Although educational research has provided some important insights into student learning, teacher development, and teaching strategies and technologies that enhance achievement in mathematics, the research has lacked a convergent knowledge base that can support systemic reform. The limited use of educational research and development (R&D) for improving practice can be attributed in part to under-investment in R&D and the consequent fragmentation of the current research effort in reading, mathematics and science (see the 1999 National Research Council Report, How People Learn: Bridging Research and Practice, http://www.nap.edu).

Two recent national reports call for heightened research attention to the area of mathematics learning and learning difficulties. In 2001, the National Research Council (NRC) of the National Academy of Sciences published *Adding It Up: Helping Children Learn Mathematics*. Comparing remediation in mathematics to that in reading, the NRC committee pointed out that there are few supplementary interventions and there is little targeted enrichment in mathematics that can help students overcome specific difficulties. The committee also emphasized the crucial importance of school-based instruction for math, given that children are likely to spend little time voluntarily exercising mathematics skills outside the classroom. In March 2002, the Rand Mathematics Study Panel, supported by the Office of Educational Research and Improvement (OERI), US Department of Education, distributed a draft report for comment. This report, *Mathematical Proficiency for All Students: Toward a Strategic Research and Development Program in Mathematics Education*, also emphasized the need for substantial research to develop an empirical base of evidence upon which new interventions can be based. It also called for research on their effectiveness once new interventions are designed and implemented. The Rand report cites previous research efforts in mathematics as fragmented, disconnected from problems of practice, and non-cumulative. In a call for well-conceived interventions, the report states that efforts at improving mathematics education often proceed without adequate evidence and independent of theory about promising courses of action. Both the NRC and Rand reports emphasize the importance of a more comprehensive view of mathematics learning.

Improve the Research of Mathematics and Science Education

The research portion of the mathematics and science Initiative is designed to establish a foundation of scientific evidence upon which efforts to improve student achievement levels in mathematics and the sciences may be based. The research agenda outline here is designed to:

- Identify the competencies essential for a work force well trained in science and mathematics
- Understand how students learn mathematics and science content
- Identify and understand student disabilities that hinder mathematics and science learning
- Develop curricula and instructional approaches that promise to enhance student achievement and identify effective programs through rigorous evaluations
- Understand what teachers need to know to be effective science and mathematics instructors and how to transmit that knowledge to them
- Enhance understanding of how schools can be organized and education policies can be formulated to support high levels of student achievement
- Develop and evaluate technologies that can advance student learning
- Develop reliable and valid assessments of mathematics and science learning and deploy them to evaluate progress in enhancing student achievement

Each of these objectives constitutes a main focus area for the mathematics and science Initiative research agenda. Investigations carried out in each of the eight areas will proceed along two parallel tracks. Research syntheses will assess the current state of scientific knowledge in given focus areas, while research studies will provide new evidence to answer questions within a particular focus area.

Identify the competencies that are essential for a workforce well trained in mathematics and the sciences.

Much mathematics and science education is based on assumptions about what students need to know that are drawn from professional consensus. These assumptions are then incorporated in standards documents such as those created by the National Council of Teachers of Mathematics. Another route to setting standards and expectations is empirically derived, based on an analysis of the competences that are required to perform mathematical and scientific tasks as they are encountered in the world of work. This aspect of the mathematics and science Initiative research agenda will identify the areas of mathematical and scientific knowledge required for professional competence in a variety of areas. It will also identify specific content knowledge and skills needed to work in professions designated as "high-need." In addition, research in this area will examine equity of educational access and investigate ways of improving the diversity of the workforce and professions that rely on mathematical and scientific skills.

Understand how students learn mathematics and science content
Basic knowledge of how people acquire, process, and apply scientific and mathematical knowledge is fundamental to the development of effective educational practice. Research that produces scientifically credible findings about student cognition, motivation, and development in mathematics and sciences will provide a foundation of knowledge to inform educational practice. Research in this area will focus on identifying the cognitive and motivational processes that under gird the acquisition and maintenance of proficiency in mathematics and the sciences.

Identify and understand student disabilities that hinder mathematics and science learning

Learning disabilities, which include principally reading disability and mathematics disability or combinations of the two, now account for more than half of all students enrolled in special education. Research in this area will be undertaken primarily by the National Institute of Child Health and Human Development (NICHD) to explore the cognitive, perceptual, behavioral, genetic, hormonal, and neurobiological mechanisms that are influential in the expression of mathematics learning abilities and learning disabilities, predictors of disabilities, and the development of preventive and treatment approaches to ameliorate mathematics-related learning disabilities.

Identify effective interventions in mathematics and science education

Research that investigates specific teaching methods and curriculum materials will help identify the most effective instructional approaches. Effective instruction requires teaching methods and instructional materials that are appropriate to the ability and maturity of the students. Work in this area will identify the instructional conditions under which students from varying abilities and backgrounds learn mathematics and science Based on available evidence, key areas crucial for supporting mathematics and science education include approaches to instruction and curricular content and format.

Understand how to develop necessary teacher skills and knowledge

Research in this area will examine the effectiveness of different models of selection, training, and professional development of mathematics and science teachers. Appropriate targets for research include the effects of different routes of entry into teaching, the different skills and abilities that are required to teach mathematics and science at different levels and for different types of students; the form and duration of pre-professional coursework that is optimal for different types of teaching; the role of induction experiences, field work, and ongoing professional development in developing effective teachers; the effects of differentiated staffing on the effectiveness of instruction at different levels of k-12 education; and mechanisms for teacher recruitment and retention.

Understand how to organize schools and design instructional policies

Work in this area will examine how the organization of schools in the form of instructional leadership, staff involvement, school and class size, scheduling of opportunities for learning; parental and community support; and accountability systems within schools affect student outcomes. Research will also investigate the effects of different district- and state-level policies such as alignment of standards and accountability systems and different forms of performance compensation.

Develop and evaluate technologies that can advance student learning

The promise of technology in addressing education challenges has yet to be realized. Mathematics and science learning are areas in which learning applications that allow students to go beyond the restrictions of their classroom and teacher need to be expanded and evaluated. Because many areas of mathematics and science learning require students to be engaged in ways that are difficult to arrange in traditional classroom instruction, this area of work will focus on

ways to deliver individualized instruction that is sensitive to student's abilities, levels, and approaches to learning.

Develop tools for assessment

Carefully developed assessment tools are required to judge the progress of students, schools, and the nation, in achieving higher levels of proficiency in mathematics and science. Building on knowledge of the foundations of mathematical and scientific competence, research on assessment will develop and test the technical adequacy (i.e., psychometric properties) and practical utility (e.g., instructional applications) of tests designed to assess proficiency levels in mathematics and science education.

Strategies for Developing A Major Academic Research Base On Effective Mathematics And Science Instruction And Assessment

- ✓ Establish a joint research agenda among ED, NSF, and NICHD to fund the research issues described above.

- ✓ Expand focus on evaluation in the "Mathematics and Science Partnerships" and require recipients to measure the program's impact on student learning.

- ✓ Complete the What Works Database and disseminate information to states and local districts.

- ✓ Support projects that develop and examine mathematics and science assessment methods and techniques, particularly those that include the use of reliable technological and other tools for determining student comprehension, application, and problem solving.

SECTION IV: Action Plan

In order to sustain a national initiative to improve the quality of student achievement in mathematics and science, the department must create an integrative, coherent long-term strategy. Working with other entities concerned about the quality of mathematics and science achievement, the Administration will focus the myriad of activities currently underway on solutions for the problems identified with the quality of teaching and learning. In addition, the Initiative will engage organizations across America to develop the motivation and perseverance of students in the pursuit of study and careers in mathematics, science, engineering and technology.

Planning the Initiative

- Working with the White House Office of Science and Technology Policy (OSTP), ED, NSF, and NASA will conduct an initial forum with other Cabinet Departments and Mission Agencies to discuss the Initiative and determine current activities underway in each entity that could be aligned to the Initiative

- A task force of interested departments and agencies will be established to finalize plans for the Mathematics and Science Initiative

- The task force will meet with the Washington representatives of a cross section of education groups; business/professional Groups; Informal Science groups; Universities; Business/Higher Ed Forum; Council of Scientific Societies; and community-based organizations to discuss the Initiative and determine current activities underway in each entity that could be aligned to the Initiative

- The task force will complete a needs assessment and establish final goals for the Initiative that will establish an integrative, coherent long-term strategy

- The task force will broaden the outreach to include state and local level groups

Initial Initiative Activities

- In the fall of 2002, the Initiative will hold the first of a series of seminars/forums with researchers and promising practice practitioners to discuss the current state of research in mathematics and science education and provide opportunities for educators applying scientifically rigorous research-based practices to share their programs

- The task force will plan and implement a public engagement campaign kickoff in winter 2003 to reinforce a series of messages crafted by the task force and the engaged departments, agencies and organizations

- The Education Department staff will integrate the Mathematics-Science Initiative with other NCLB education efforts to improve the quality of teacher preparation and teacher development:
    - Mathematics-Science Partnerships will inform the Initiative and be informed by the research findings on effective professional development strategies
    - Teacher Quality efforts will build on dissemination of research findings on effective practices in mathematics and science education to states and districts

- Mathematicians and scientists will develop consensus on what should be included in the pre-service course work and in-service professional development for teachers of mathematics
- Organizations engaged in mathematics and science research and education will assist in the development of specifications and recommendations for state assessment development efforts

Long Term Initiative Activities

The impact of the Initiative will depend upon the creation and dissemination of definitive strategies that can be implemented at schools across America to improve the quality of teaching and learning of mathematics and science.

Increasing Public Engagement in Mathematics and Science education

- The Education Department will fund the establishment of a national center to create state Scholars programs and engage the business community in each state to encourage young people to enroll in a rigorous high school course of study, including at least three years of mathematics and three years of science.

- The task force made up of representatives of education groups; business/professional groups; informal science groups; universities; Business/Higher Ed Forum; Council of Scientific Societies; and community-based organizations will develop and implement a series of messages for students, parents and the public about the need for students to study mathematics and science for informed decision making as well as careers in mathematics and science related fields.

Improving Teaching and Learning in Mathematics and Science

- To improve future rounds of applications for funding for the Mathematics-Science Partnerships, the ED and NSF will train university and school district partners about the requirements and expectations of the grant program and stimulate the development of high quality projects.

- With the feedback to initial applicants, as well as outreach to educate the community, future rounds of grants should result in higher quality proposals that can serve to identify best practices in mathematics-science education.

- The Administration will convene university presidents, deans of colleges of education and of arts and sciences, chief state school officers, and school district superintendents to initiate conversations regarding collaboration in the improvement of mathematics and science education.

- A PreK-20 task force will identify strategies to increase the mathematics and science pipeline from Pre-Kindergarten through post-doctoral studies. The professionals who teach at each level must communicate to ensure that early experiences establish the foundation for later learning. This will enable universities and school districts to influence the preparation of new teachers as well as the professional development of current teachers at every level.

- Parents and students, as well as teachers, will learn about the relationship between early course-taking decisions and later career opportunities.

Expanding the Research Agenda in Mathematics and Science Education

- Phase I of the research component will focus on developing a synthesis of available evidence to inform the effort to improve student achievement in mathematics and the sciences. These activities will provide guidance for immediate efforts to raise student achievement and identify specific knowledge gaps in research that supports the improvement of student achievement in mathematics and science. Phase I activities will include meta-analytic and comprehensive reviews of research and programs meant to support the national effort to improve student achievement in mathematics and the sciences.

- Phase II will focus on the systematic development of a comprehensive, coordinated, interagency research agenda that will develop a foundation of scientific knowledge needed to improve student achievement in mathematics and the assessment of current research knowledge. ED, NSF, and NICHD will initiate new programs of research designed to produce an evidentiary foundation to improve student achievement in mathematics and the sciences.

Performance Measures

The ultimate purpose of this Initiative is to increase the achievement of students in mathematics and science as stated in the ED Strategic Plan for 2002-2007:

Performance Measures for Objective 2.2

Objective 2.2 Mathematics Achievement		Performance Targets					
		'02	'03	'04	'05	'06	'07
State Mathematics Assessments	**All Students**. The number of states meeting their targets for eighth-grade mathematics achievement for all students.	N/A	45	45	45	45	45
	Low-Income Students. The number of states meeting their targets for eighth-grade mathematics achievement for low-income students.	N/A	45	45	45	45	45
	African American Students. The number of states meeting their targets for eighth-grade mathematics achievement for African American students.	N/A	45	45	45	45	45
	Hispanic Students. The number of states meeting their targets for eighth-grade mathematics achievement for Hispanic students.	N/A	45	45	45	45	45
	Students with Disabilities. The number of states meeting their targets for eighth-grade mathematics achievement for students with disabilities.	N/A	45	45	45	45	45
	English Language Learners. The number of states meeting their targets for eighth-grade mathematics achievement for English language learners.	N/A	45	45	45	45	45

Note: Using the 2001-2002 school year as a baseline, states are required to set the same annual achievement target for all students and for several student subgroups, starting with the 2002-2003 school year. (This equates to the Department's 2003 fiscal year, which is the first year this indicator can be measured.) Under the *No Child Left Behind Act*, these targets must increase at least every three years for the next 12 years, when 100 percent of all students within all subgroups are expected to achieve proficiency. Therefore, while the targets listed above are stable, student achievement will actually need to

improve steadily in order to meet these goals. When a state does not test students in the eighth-grade, results from sixth- or seventh-grade assessments will be used instead.

Objective 2.2 Mathematics Achievement		Performance Targets					
		'02	'03	'04	'05	'06	'07
NAEP Mathematics	**All Students.** The percentage of all 8th grade students scoring at or above the basic and proficient levels on the NAEP.						
	2000 Basic Baseline = 63%	X	64	X	65	X	67
	2000 Proficient Baseline = 26%	X	27	X	28	X	30
	Low-Income Students. The percentage of low-income 8th grade students scoring at or above the basic and proficient levels on the NAEP.						
	2000 Basic Baseline = 42%	X	43	X	45	X	50
	2000 Proficient Baseline = 10%	X	11	X	13	X	18
	African American Students. The percentage of African American 8th grade students scoring at or above the basic and proficient levels on the NAEP.						
	2000 Basic Baseline = 30%	X	31	X	33	X	38
	2000 Proficient Baseline = 5%	X	6	X	8	X	13
	Hispanic Students. The percentage of Hispanic 8th grade students scoring at or above the basic and proficient levels on the NAEP.						
	2000 Basic Baseline = 39%	X	40	X	42	X	47
	2000 Proficient Baseline = 8%	X	9	X	11	X	16
	Students with Disabilities. The percentage of 8th grade students with disabilities scoring at or above the basic and proficient levels on the NAEP. 2000 Basic Baseline = 22%	X	23	X	25	X	30
	2000 Proficient Baseline = 4%	X	5	X	7	X	12
	Limited English Proficient Students. The percentage of 8th grade limited English proficient students scoring at or above the basic and proficient levels on the NAEP.						
	2000 Basic Baseline = 21%	X	22	X	24	X	29
	2000 Proficient Baseline = 2%	X	3	X	5	X	10

Note about achievement targets: These targets assume a 4-percentage point gain for all students from 2000 to 2007 and an 8-percentage point gain for each subgroup, thus narrowing the achievement gaps. While this is very ambitious when compared to long-term national trend lines, several states have shown that such rapid progress is possible. For example, from 1992 to 2000, Hispanic students in six states (Ohio, Maryland, North Carolina, West Virginia, Tennessee and Massachusetts) made gains of at least 8

percentage points on the eighth-grade NAEP mathematics assessment, and African-American students in Nebraska and New York made gains of at least six percentage points. At the basic level, African American students in 14 states achieved gains of at least 8 percentage points on the 8th grade NAEP mathematics assessment, and Hispanics gained at least 8 percentage points in 18 states.

Note: Under the current schedule, NAEP Mathematics will not be given in 2002, 2004 and 2006.

Objective 2.2 Science Achievement		Performance Targets					
		'02	'03	'04	'05	'06	'07
NAEP Science	**All Students.** The percentage of all 8th grade students scoring at or above the basic and proficient levels on the NAEP. 2000 Basic Baseline = 59%	X	X	X	61	X	X
	2000 Proficient Baseline = 30%)	X	X	X	33	X	X
	Low-Income Students. The percentage of low-income 8th grade students scoring at or above the basic and proficient levels on the NAEP. 2000 Basic Baseline = 33%	X	X	X	39	X	X
	2000 Proficient Baseline = 11%	X	X	X	17	X	X
	African American Students. The percentage of African American 8th grade students scoring at or above the basic and proficient levels on the NAEP. 2000 Basic Baseline = 24%	X	X	X	30	X	X
	2000 Proficient Baseline = 6%	X	X	X	12	X	X
	Hispanic Students. The percentage of Hispanic 8th grade students scoring at or above the basic and proficient levels on the NAEP. 2000 Basic Baseline = 33%	X	X	X	39	X	X
	2000 Proficient Baseline = 10%	X	X	X	16	X	X
	Students with Disabilities. The percentage of 8th grade students with disabilities scoring at or above the basic and proficient levels on the NAEP. 2000 Basic Baseline = 28%	X	X	X	34	X	X
	2000 Proficient Baseline = 8%	X	X	X	14	X	X
	Limited English Proficient Students. The percentage of 8th grade limited English proficient students scoring at or above the basic and proficient levels on the NAEP. 2000 Basic Baseline = 12%	X	X	X	18	X	X
	2000 Proficient Baseline = 3%	X	X	X	9	X	X

Note about achievement targets: These targets assume a 3-percentage point gain for all students from 2000 to 2005 and a 6-percentage point gain for each subgroup, thus narrowing the achievement gaps. This rate of change is proportionate to the targets set for reading and mathematics (considering the shorter timeline). Note: Under the current schedule, NAEP Science will next be given in 2005.

[i] U.S. Commission on National Security/21st Century. February 15, 2001. *Road Map for National Security: Imperative for Change*. Washington, DC: GPO, Chapter II, pp. 30-46.

[ii] See Website http://www.ed.gov/offices/OESE/SIP/programs/ttt.html

[iii] See Website http://www.ed.gov/offices/OESE/SIP/programs/ttt2.html

[iv] See Website http://www.nochildleftbehind.gov/

[v] U.S. Department of Education, National Center for Education Statistics. 2002. *The Condition of Education 2002*. Washington, DC: GPO, p. 138 and 145.

[vi] U.S. Department of Education, National Center for Education Statistics. 2002. *The Condition of Education 2002*. Washington, DC: GPO, p. 138.

[vii] The Center for Education Reform. September 24, 2001. News Alert. *NAEP Mathematics Standards Weak.* Washington, DC: The Center for Education Reform. http://edreform.com/press/2001/NAEP.htm.

[viii] U.S. Department of Education, National Center for Education Statistics. 2001. *The Nation's Report Card: Mathematics 2000.* Washington, DC: GPO, pp. 58-68.

[ix] U.S. Department of Education, National Center for Education Statistics. 2002. *The Nation's Report Card: Science Highlights 2000.* Washington, DC: GPO, p. 8.

[x] U.S. Department of Education, National Center for Education Statistics. 2002. *The Condition of Education 2002*. Washington, DC: GPO, p. 59.

[xi] U.S. Department of Education, National Center for Education Statistics. 2002. *The Condition of Education 2002*. Washington, DC: GPO, p. 150.

[xii] The National Commission on Mathematics and Science Teaching for the 21st Century. September 2000. *Before It's Too Late.* Washington, DC: GPO, p. 12.

[xiii] Whelan, Karl. February 2000. Paper for the Federal Reserve Board, Division of Research and Statistics. *Computers, Obsolescence, and Productivity.* Washington, DC: Federal Reserve Board, p. 26.

[xiv] The National Commission on Mathematics and Science Teaching for the 21st Century. September 2000. *Before It's Too Late.* Washington, DC: GPO, p. 12.

[xv] U.S. Department of Labor, Bureau of Labor Statistics. 2000. *Occupational Outlook Handbook, 2002-03 Edition.* Washington, DC: GPO. Table 3.

[xvi] U.S. Department of Education, Office of the Under Secretary, Planning and Evaluation Service. 1997. White paper. *Mathematics Equals Opportunity.* Washington, DC: GPO, p. 6.

[xvii] U.S. Department of Education, National Center for Education Statistics. 1999. *Literacy in the Labor Force: Results from the National Adult Literacy Survey.* Washington, DC: GPO, p. 126. Publication #1999-740.

[xviii] National Science Board. 2000. *Science and Engineering Indicators – 2000.* Arlington, VA: National Science Foundation, p. 3-2. NSB-00-1.

[xix] Bayer Corporation. July 11, 2000. Press release. *The Bayer Facts of Science Education VI: Americans' Views on Science, Technology, Education and the Future.* Pittsburgh, Penn.

[xx] Public Agenda. 1997. *Given the Circumstances: Teachers Talk about Public Education Today.* New York, NY: Public Agenda.

[xxi] Bayer Corporation. May 21, 2002. Press release. *The Bayer Facts of Science Education VIII: College Students Look Ahead.* Pittsburgh, Penn.

[xxii] Sanders, W., and Rivers, J. 1996. *Cumulative and Residual Effects of Teachers on Future Student Academic Achievement*. Knoxville, Tenn.: University of Tennessee Value-Added Research and Assessment Center.

[xxiii] U.S. Department of Education, National Center for Education Statistics. 2002. *Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987-88 to 1999-2000.* Washington, DC: GPO, Tables B-11 and B-12.

[xxiv] Ibid.

[xxv] U.S. Department of Education, Office of the Under Secretary, Policy and Program Studies Service. June 14, 2002. *Internal Analyses of Baccalaureate and Beyond 1993:1997.*

[xxvi] Ibid.

[xxvii] Ibid.

[xxviii] The Education Trust, Inc. 1999. *Not Good Enough: A Content Analysis of Teacher Licensing Examinations.*

[xxix] U.S. Department of Education, Office of Postsecondary Education. 2002. *Meeting the Highly Qualified Teachers Challenge*. Washington, DC.

[xxx] Raymond, Margaret, S. Fletcher, and J. Luque. 2001. *Teach for America: An Evaluation of Teacher Differences and Student Outcomes in Houston, Texas.*

[xxxi] The Center for Education Reform. September 24, 2001. "Testimony of John Hoven at the National Assessment Governing Board on the draft 2004 Mathematics Framework for NAEP." Washington, DC.

[xxxii] U.S. Department of Education, National Center for Education Statistics. 1999. *TIMMS-R Benchmarking Study.* Washington, DC: GPO.

[xxxiii] U.S. Department of Education, National Center for Education Statistics. 2001. *The Nation's Report Card: Mathematics 2000.* Washington, DC: GPO, p. 160.

[xxxiv] U.S. Department of Education, Office of the Under Secretary. Planning and Evaluation Service. 2000. *Does Professional Development Change Teaching Practice? Results from a Three-Year Study*. Washington, DC: GPO.

[xxxv] Cohen, David K. and Heather C. Hill, *Learning Policy: When State Education Reform Works*. 2001.

[xxxvi] Whitehurst, Grover J. March 5, 2002. Paper for the White House Conference on Preparing Tomorrow's Teachers. *Research on Teacher Preparation and Professional Development.* Available at Website: http://www.ed.gov/inits/preparingteachersconference/whitehurst.html.